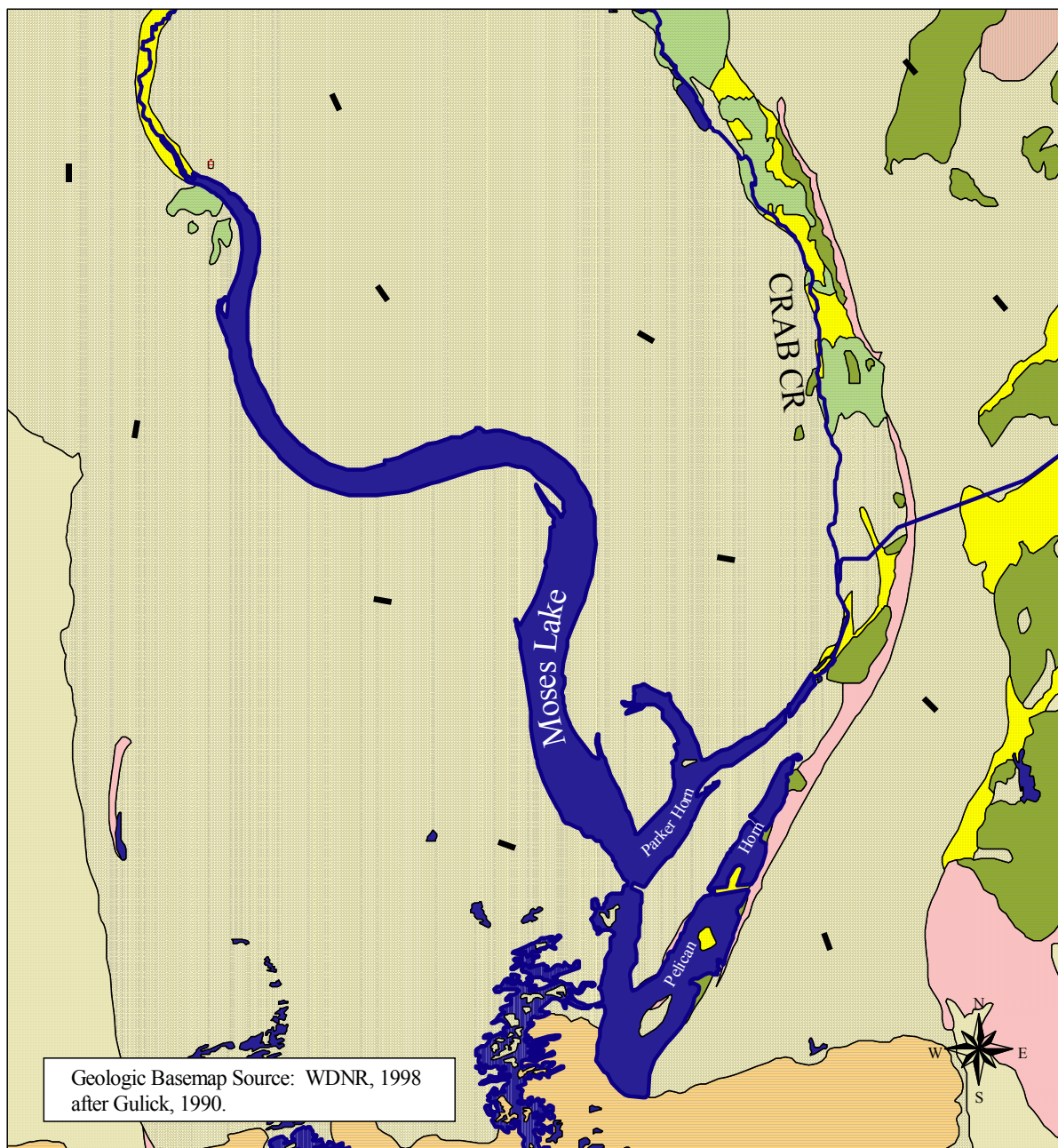


# Moses Lake TMDL Groundwater Study

December 2002

Charles Pitz  
Wash. St. Dept. of Ecology  
Environmental Assessment Program



#### Legend

- Alluvium
- Loess
- Lacustrine deposits
- Pleistocene Flood Deposits (grvl)
- Pleistocene Flood Deposits (slt/snd)
- Ringold Formation
- Priest Rapids Wanapum
- Roza Wanapum
- Water

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General Groundwater Flow Direction  
in Surficial Aquifer

**Figure 4 -  
Surficial Geology Map  
Moses Lake TMDL  
Groundwater Study**

1 0 1 2 Miles

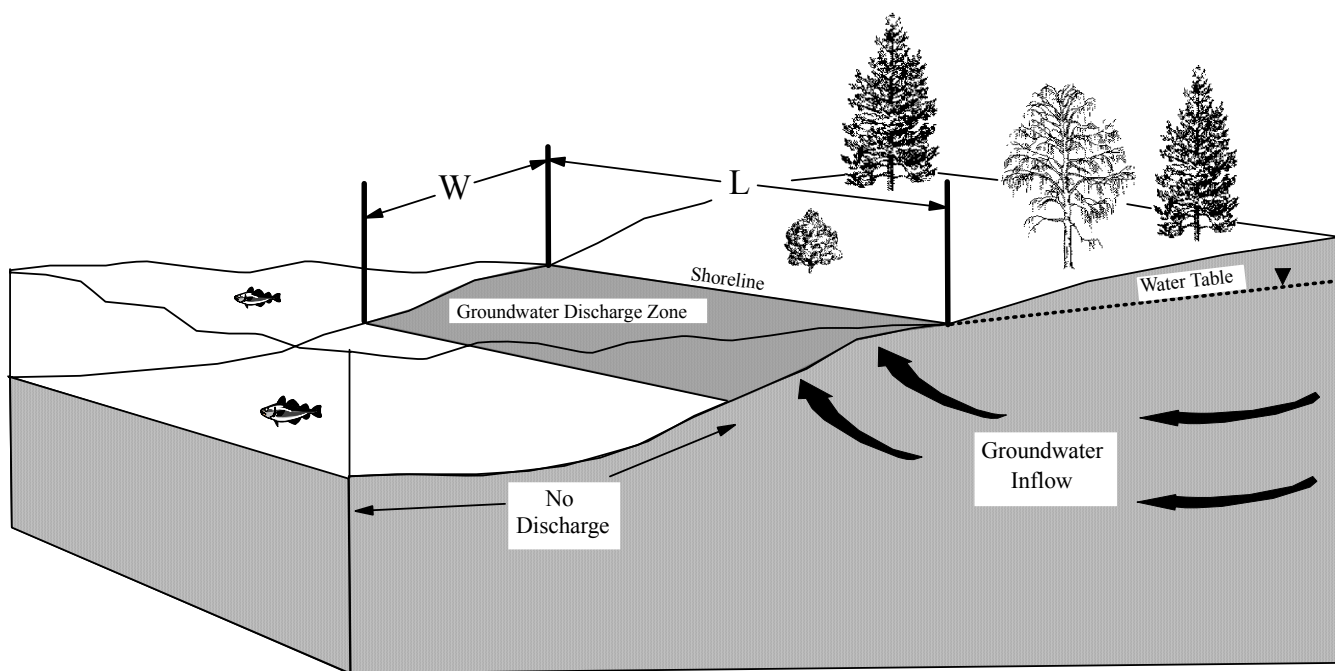


Figure F-1  
Conceptual Diagram of Groundwater  
Discharge and Subsurface  
Solute Transport to Moses Lake

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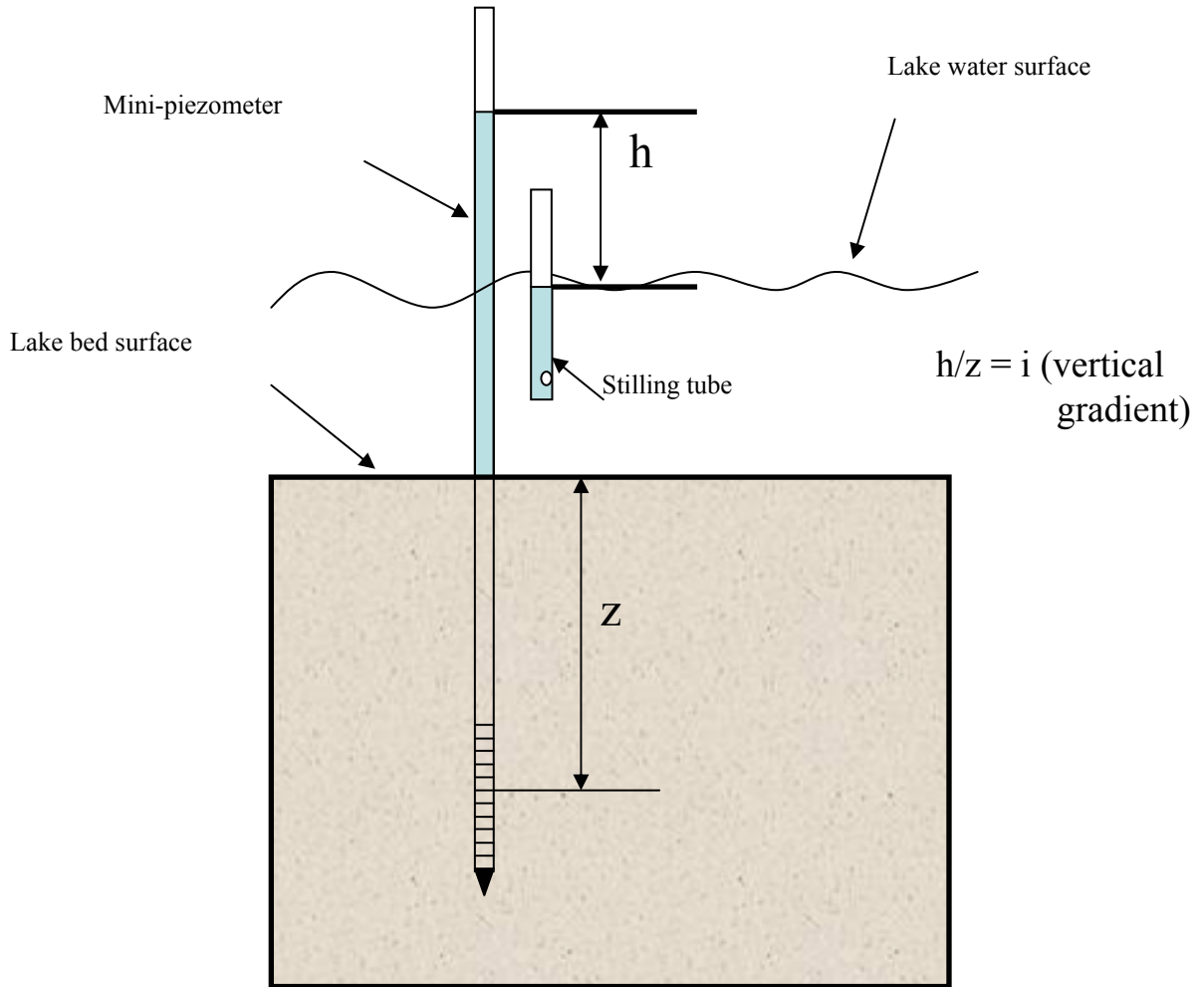
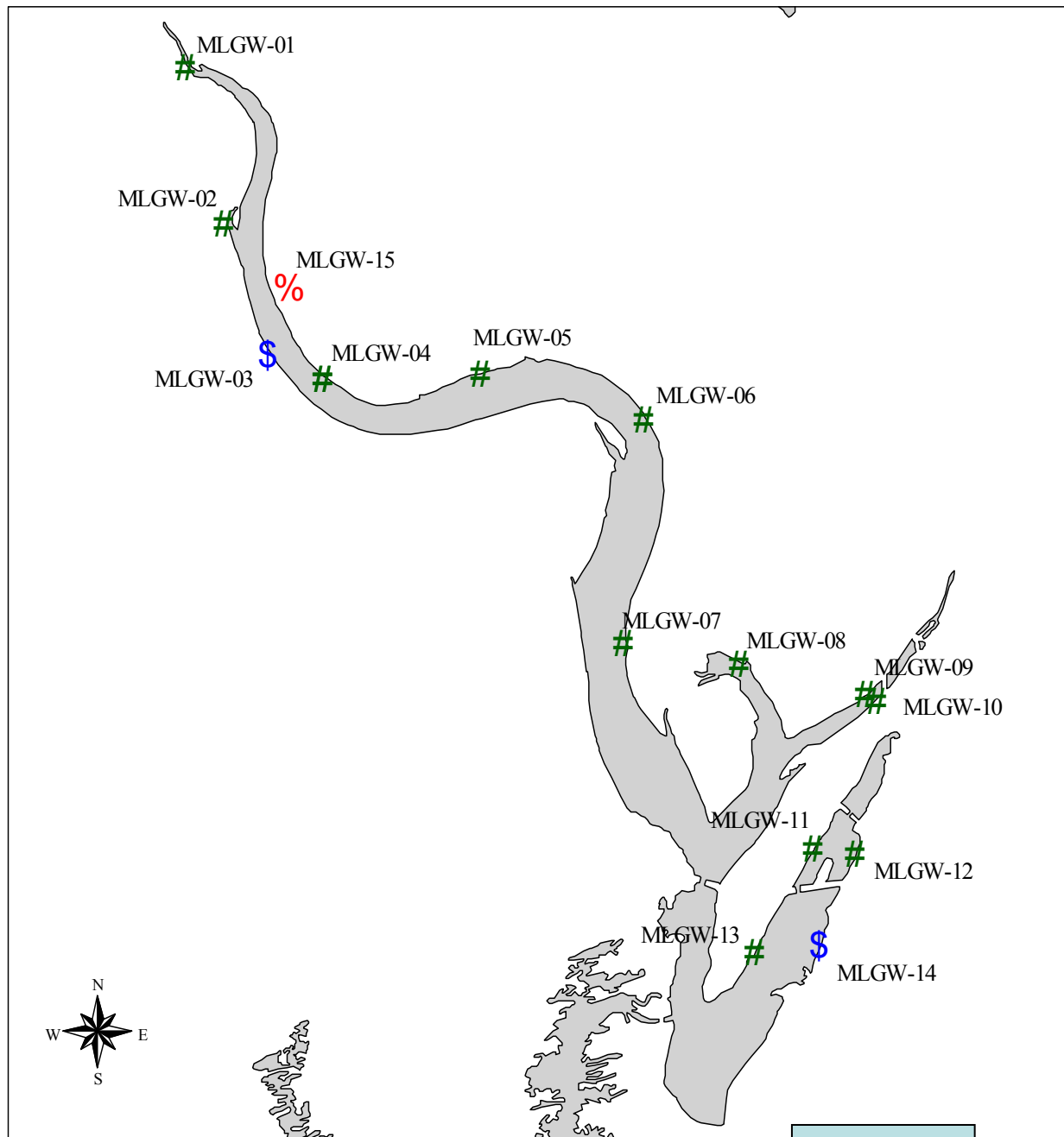


Figure 8 – Measurement Method to  
Estimate Vertical Hydraulic Gradient  
In Study Piezometers  
Moses Lake TMDL Groundwater Study

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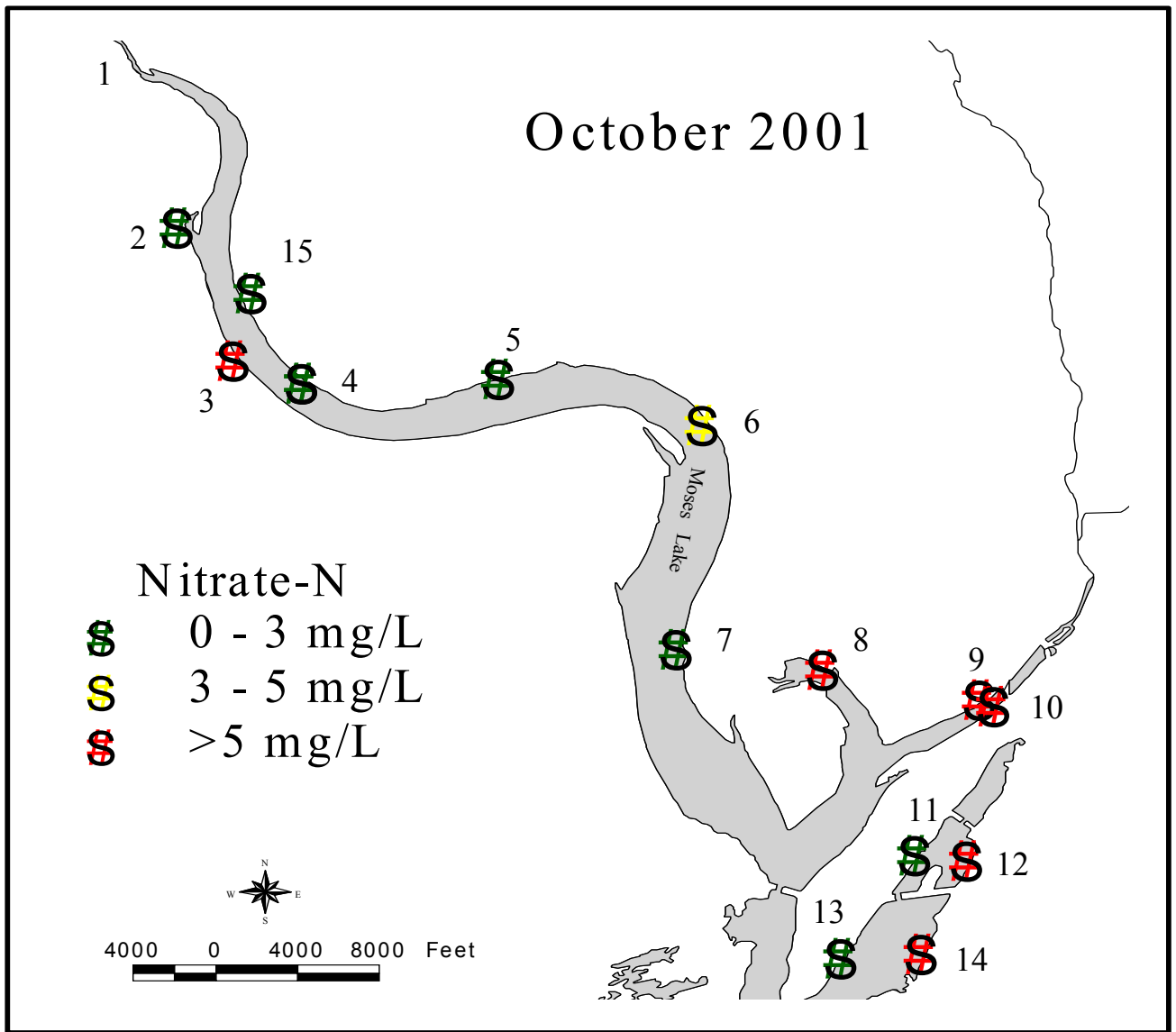


### Legend

- # Lake-bed mini-piezometer
- \$ Spring or Seep
- % Well

1 0 1 2 Miles

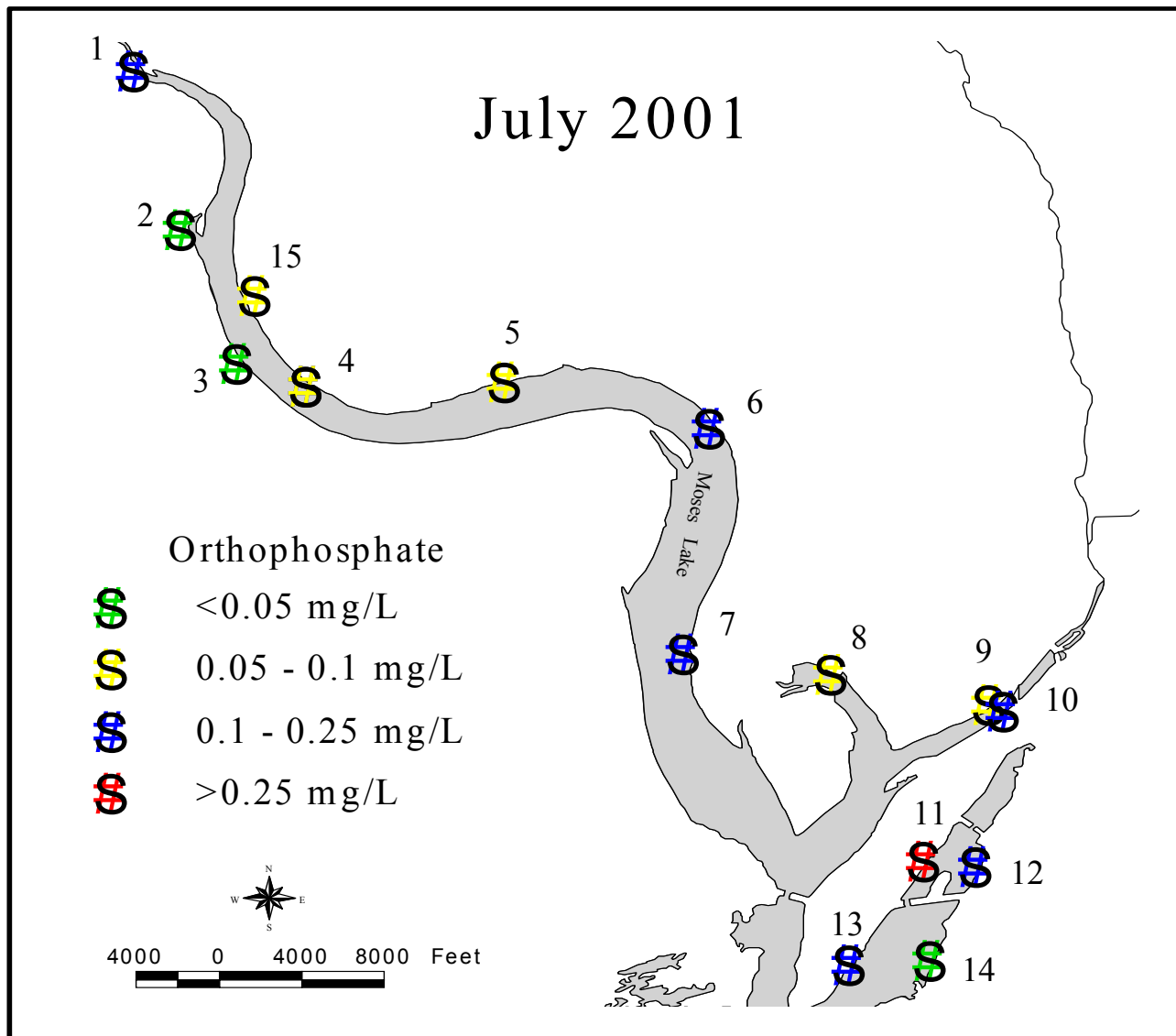
Figure 7 -  
Sampling Station Location Map  
Moses Lake TMDL Groundwater Study



Number next to station represents station name

## Groundwater Nitrate-N Concentration Oct. 2001

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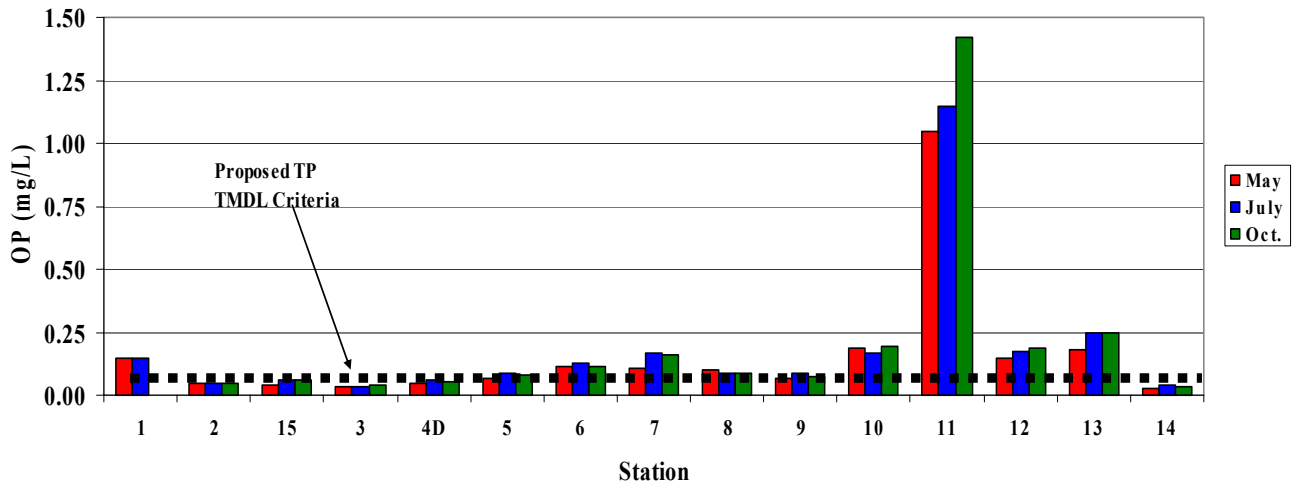


Number next to station represents station name

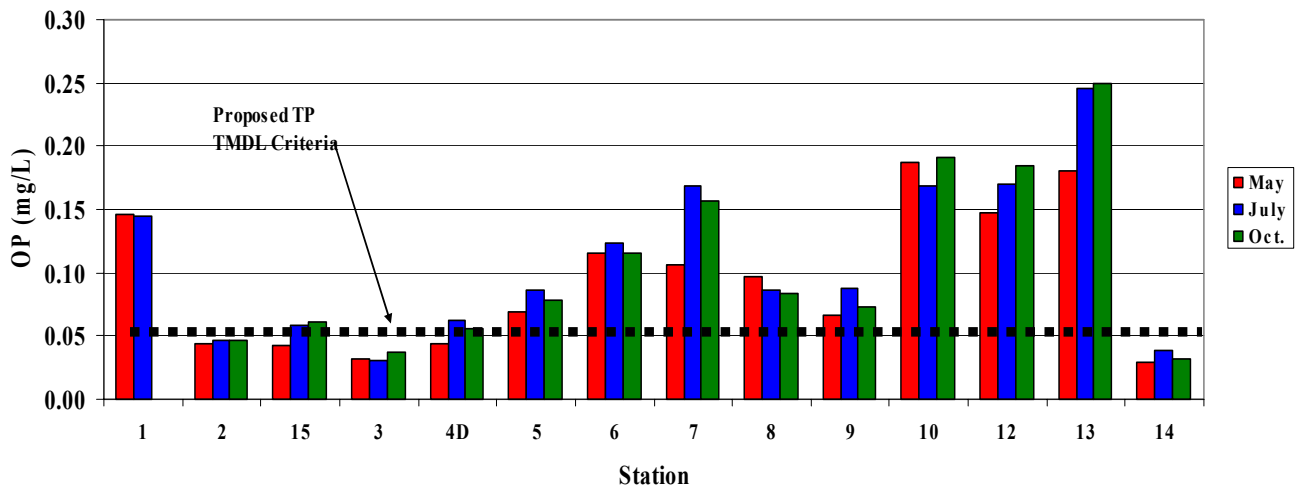
## Orthophosphate (OP) Concentration July 2001

DRAFT

# Orthophosphate Concentration in Groundwater Moses Lake



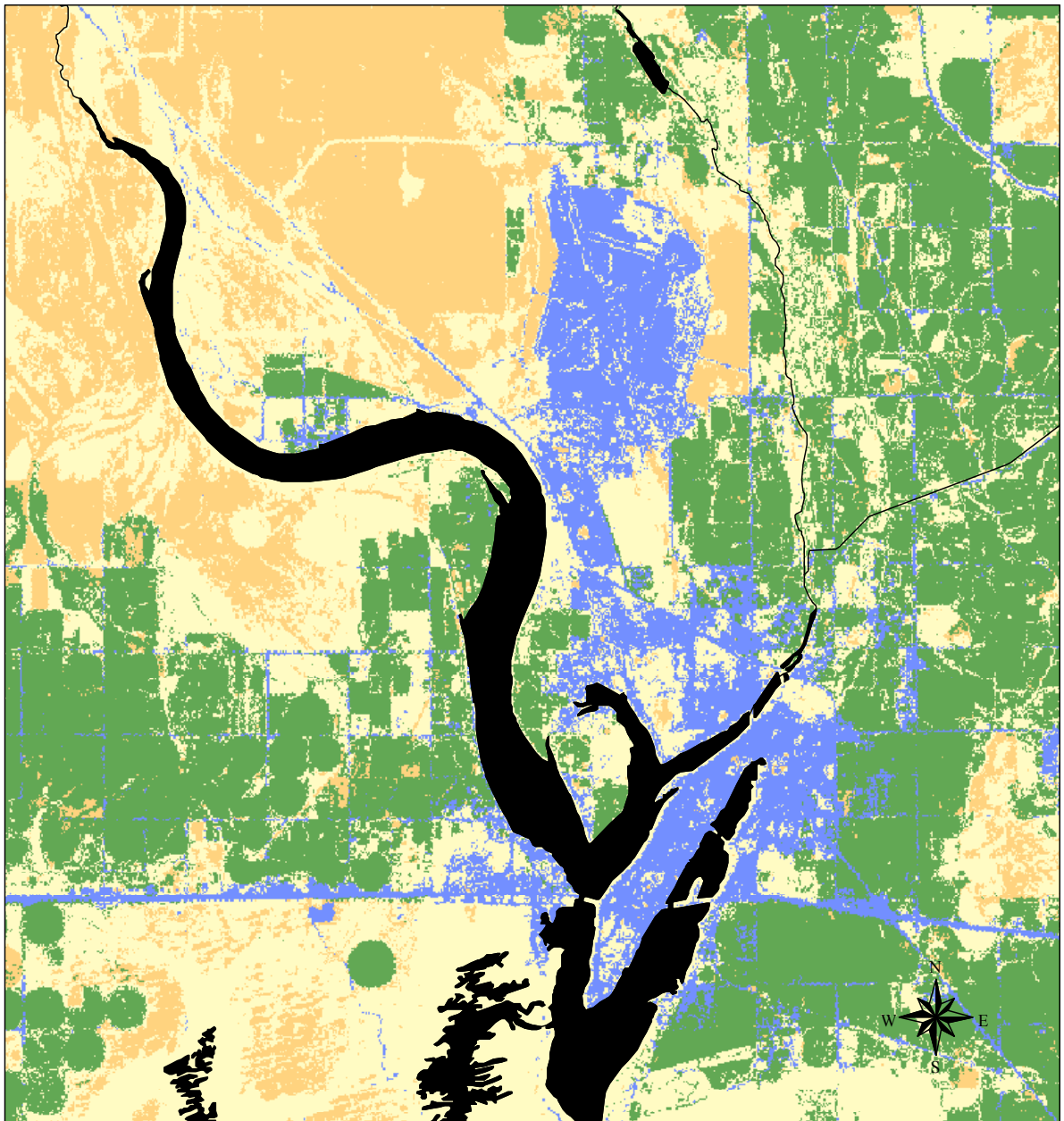
# Orthophosphate Concentration in Groundwater Moses Lake (Station MLGW-11 removed)



Note: Stations on the lower axis of the graphs are arranged in approximate geographic order from north to south

Figure 13 –  
Orthophosphate Concentration in Groundwater  
Moses Lake TMDL Groundwater Study

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Map Source: USGS, 1999


**Legend - Generalized Land Use**

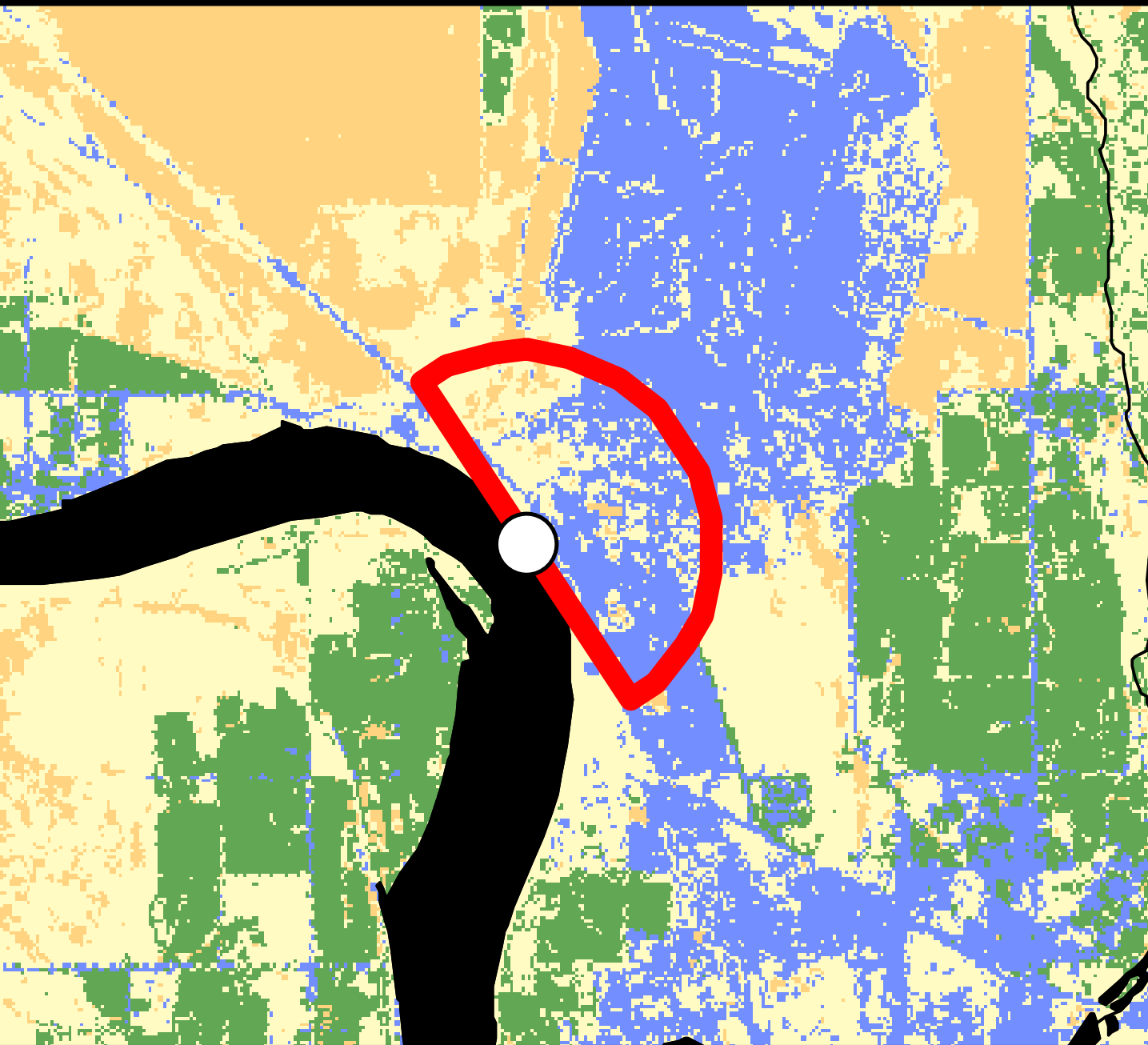
- Water
- Developed Lands
- Undeveloped Shrubland/Forest
- Grassland/Grazing
- Agricultural Land

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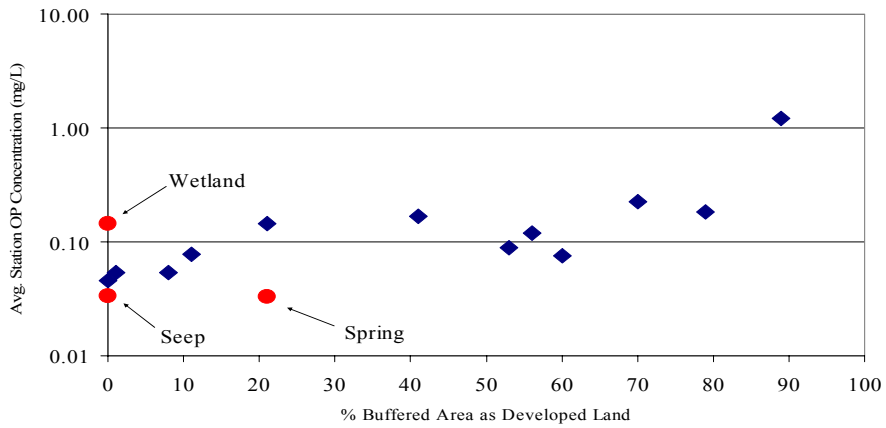
**Figure 3 -**  
Generalized Land Use Map  
Moses Lake TMDL  
Groundwater Study

1 0 1 2 Miles

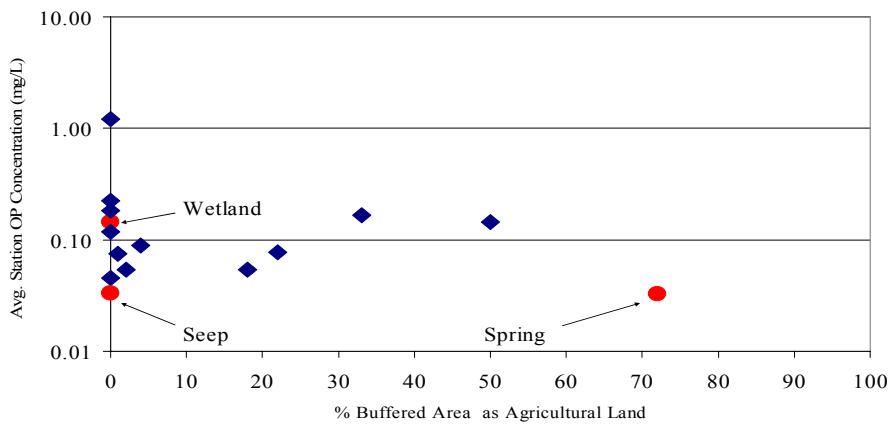




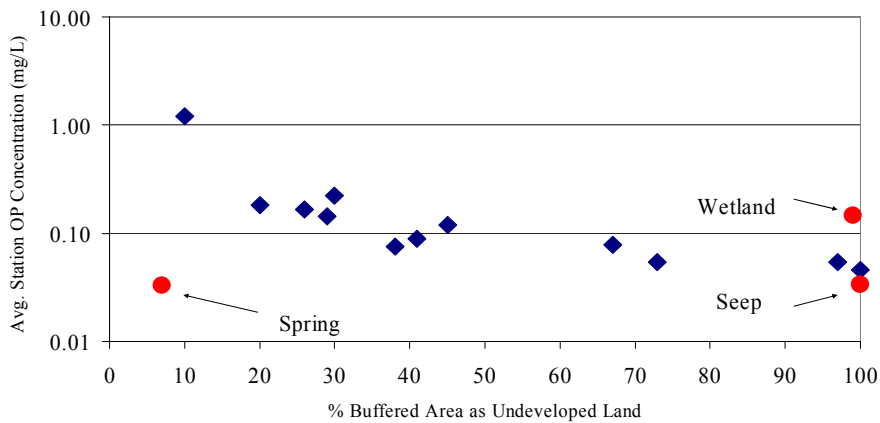
Developed Land Use vs. OP Concentration



Agricultural Land Use vs. OP Concentration

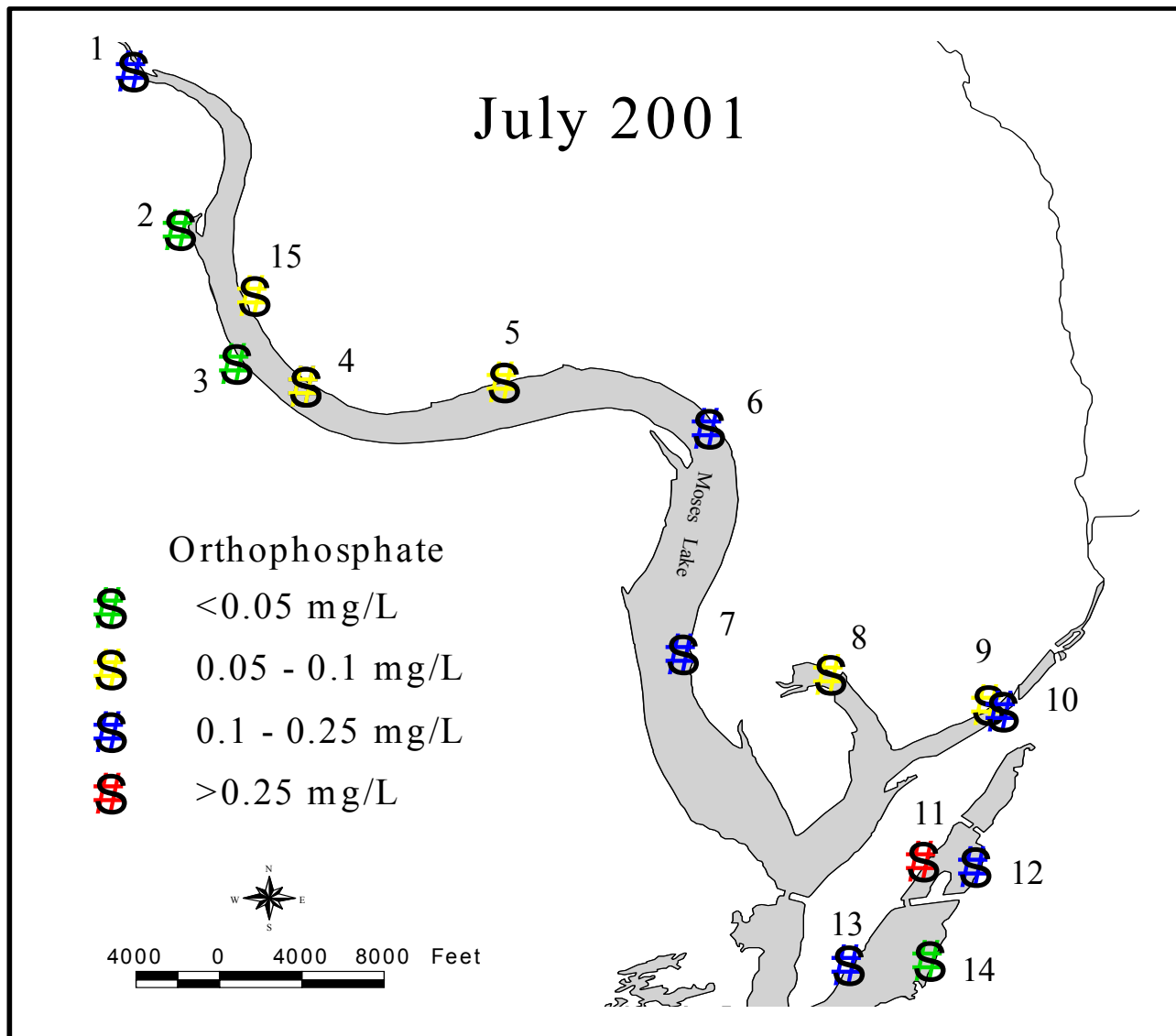


Undeveloped Land Use vs. OP Concentration



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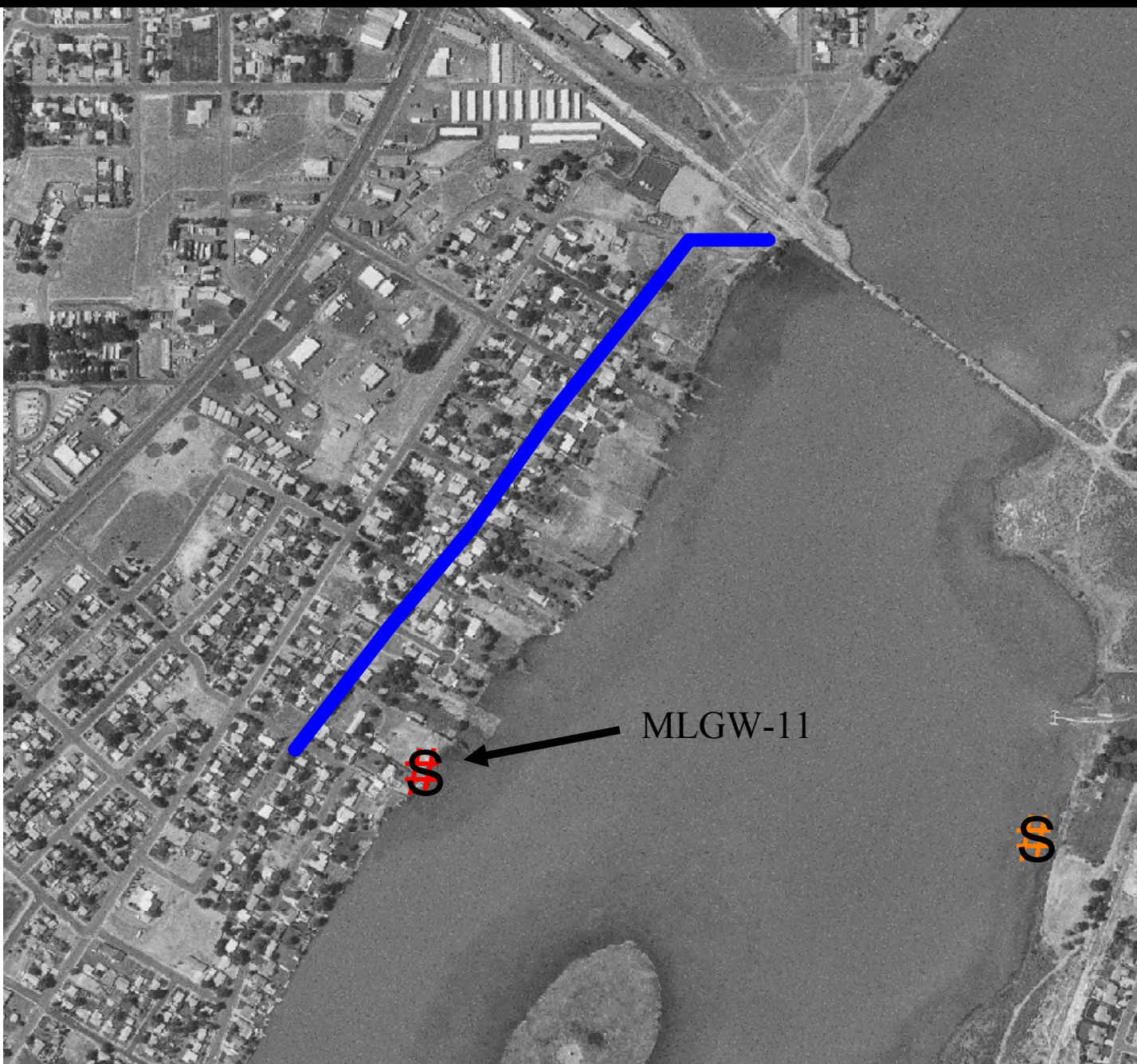
Figure 17 – Comparison of Vicinity Land Use to Orthophosphate Concentration  
Moses Lake TMDL Groundwater Study



Number next to station represents station name

## Orthophosphate (OP) Concentration July 2001

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**Moses Lake Sewer Main  
Relining/Replacement  
Project - Summer/Fall 2001**

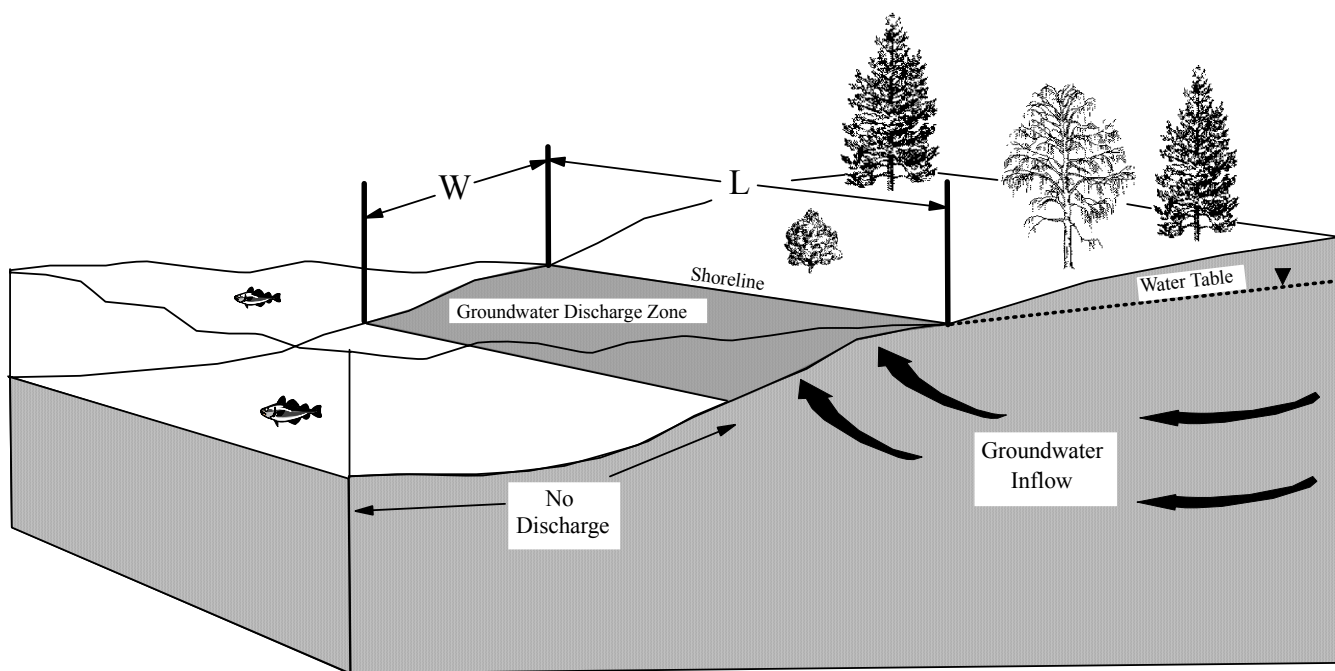


Figure F-1  
Conceptual Diagram of Groundwater  
Discharge and Subsurface  
Solute Transport to Moses Lake

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# Estimating Phosphorus Loading by Groundwater Discharge

- First estimate the volume of groundwater discharge by combining:
  - estimates of the permeability of the discharge zone sediments
  - estimates of the area of discharge
  - measurements of the hydraulic gradient in the discharge zone
- Vary each of the values used in the calculations over a range considered reasonable for the study area

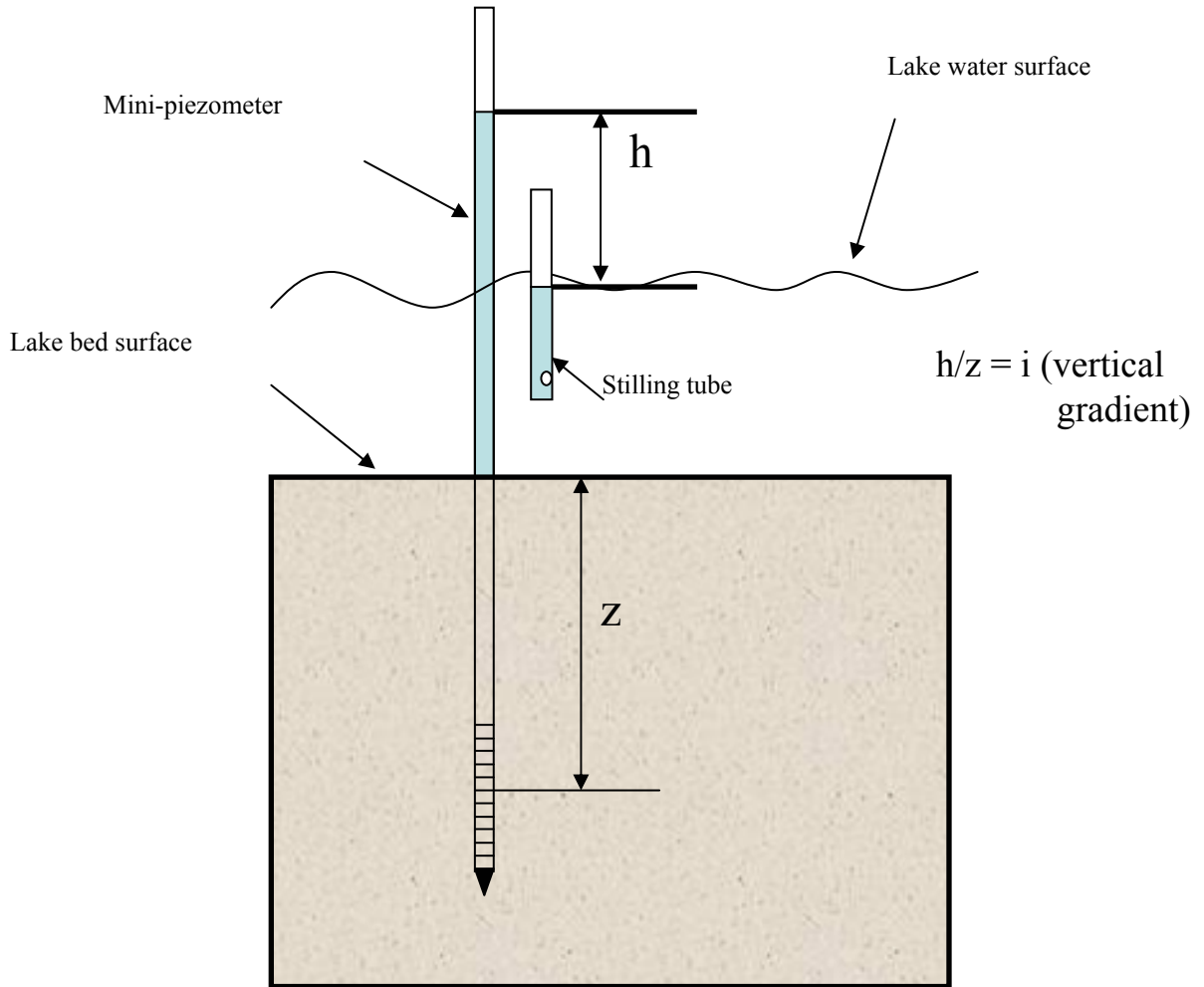


Figure 8 – Measurement Method to  
Estimate Vertical Hydraulic Gradient  
In Study Piezometers  
Moses Lake TMDL Groundwater Study

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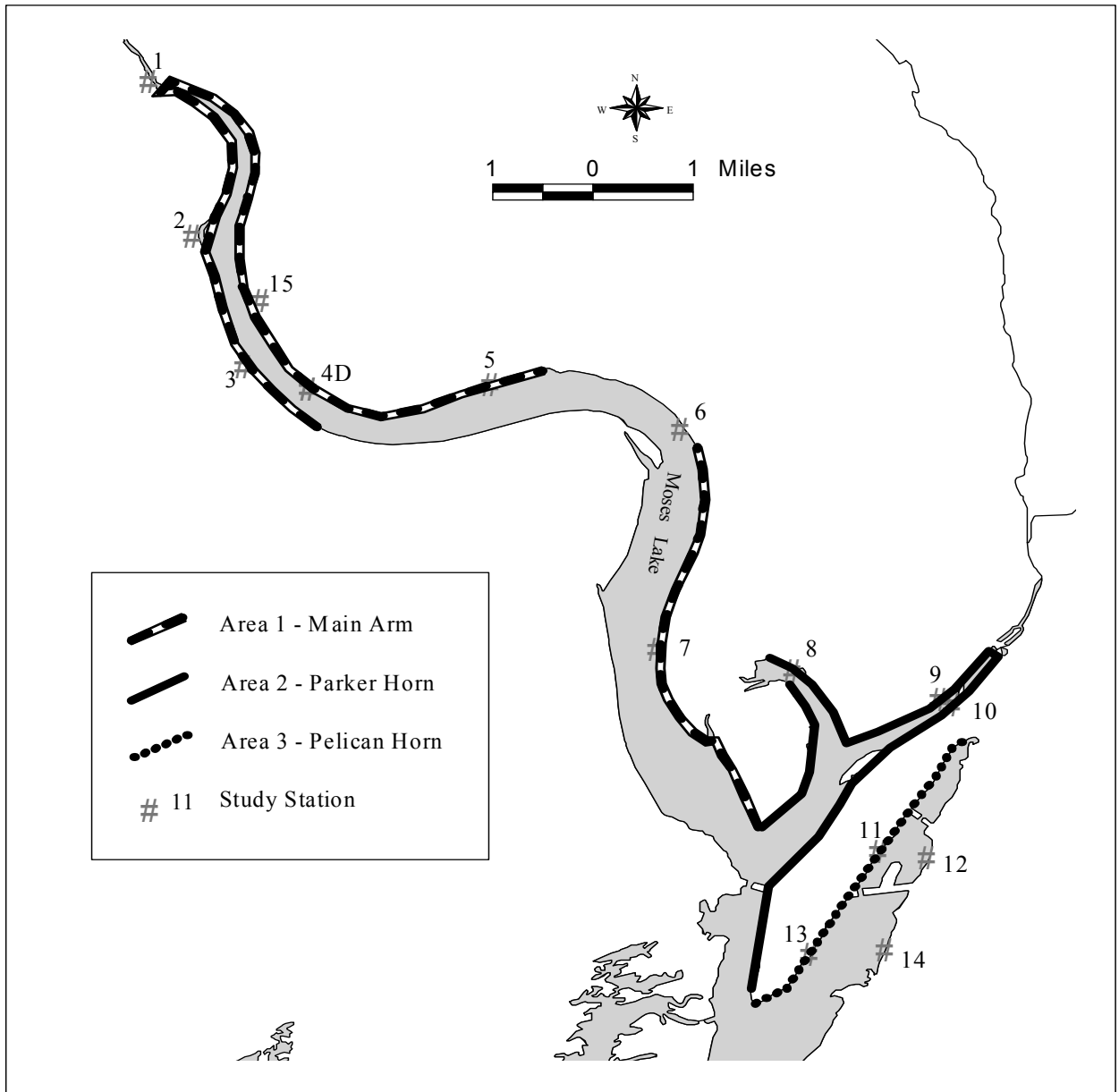


Figure F-3  
Groundwater Discharge Areas

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# Groundwater Loading (cont.)

- Combine volume-of-discharge estimates with measured concentration of orthophosphate to estimate the amount (mass) of phosphorus input to the lake over a given timeframe
- Final estimates predict a range between ~400 - 40,000 kg orthophosphate per year is input to the lake by groundwater discharge

# Groundwater Loading (cont.)

- Value between 10,000-20,000 kg phosphorus per year considered the best estimate
- Estimates don't account for what happens to the phosphorus once it enters the lake

# Summary of Findings

- Evidence indicates Moses Lake is a “flow-through” lake from a groundwater standpoint
- Majority of the groundwater flow entering the lake is from the very high permeability flood deposits
- Coarse deposits around Moses Lake have a limited ability to immobilize phosphorus in the aquifer

# Findings (cont.)

- Evidence indicates that the area background condition for orthophosphate (the main form of phosphorus in groundwater) is  $<0.05$  mg/L
- Evidence indicates values measured in groundwater above  $0.05$  mg/L are not derived from a natural (mineralogical) source

# Findings (cont.)

- Orthophosphate concentrations (as well as other measures) generally increase from north to south along the lake
- 75% of the study groundwater stations showed orthophosphate  $>0.05$  mg/L
- Results largely confirm Bain's previous findings

# Findings (cont.)

- Two key factors appearing to control phosphorus occurrence in groundwater discharging to the lake:
  - If the geochemical conditions are right
  - If there is a nearby source
- Increases in phosphorus concentrations in discharging groundwater are related to the degree of urban development

# Findings (cont.)

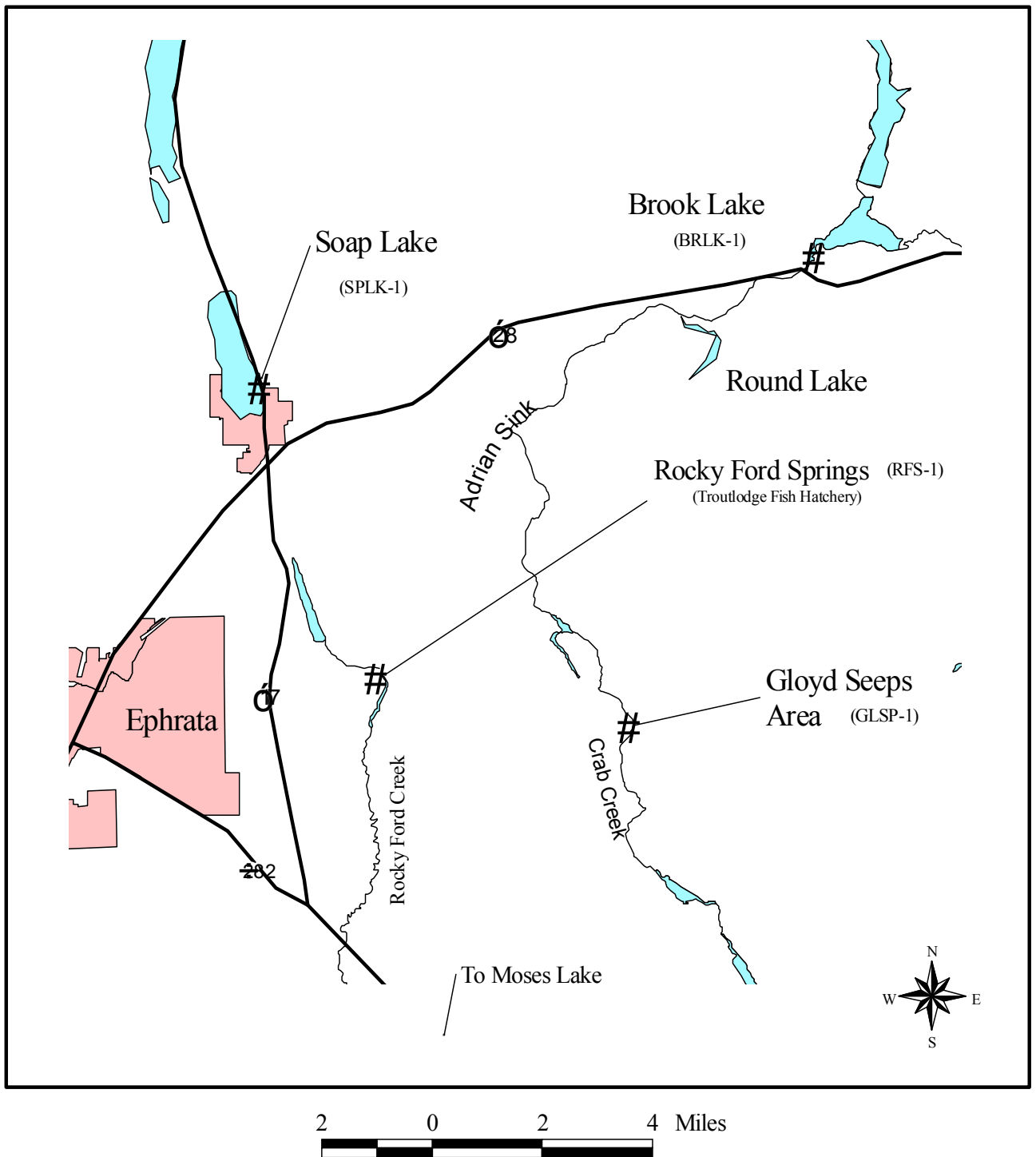
- Collectively, the data suggests the release of wastewater to the aquifer is the primary source of phosphorus in groundwater entering the lake

# Findings (cont.)

- Infiltration to the aquifer from irrigated agriculture may elevate the ambient condition of phosphorus in area groundwater, but does not appear to be a major contributor of phosphorus to the lake via the groundwater pathway

# Findings (cont.)

- Other study areas have shown that a reservoir of phosphorus in an aquifer can impact groundwater quality for many years after loading has stopped – further study?



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Figure A-1  
Geochemistry Sampling Locations  
Rocky Ford Springs Source Evaluation

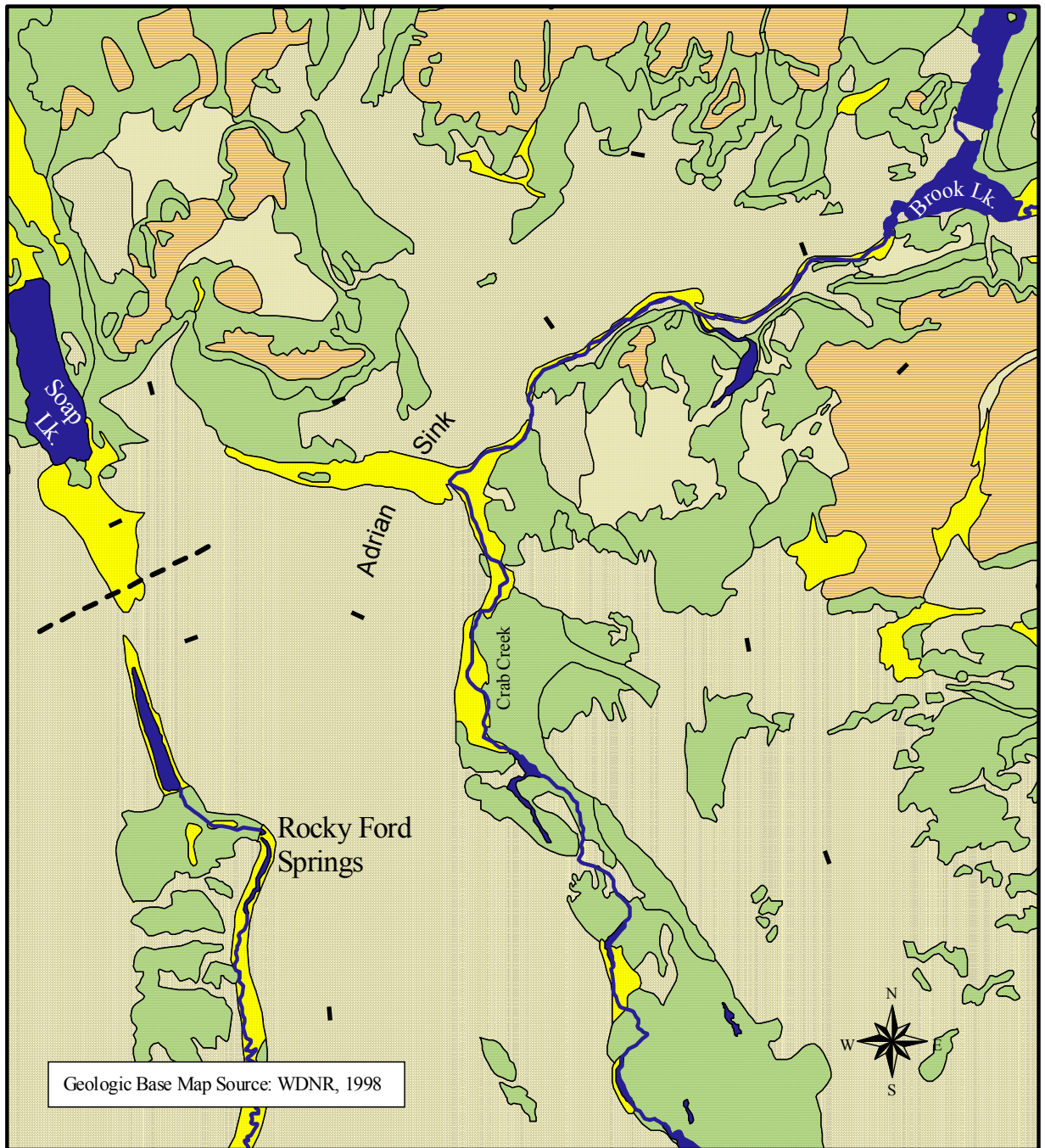










Figure A-2  
 Surficial Geology and  
 General Groundwater Flow Direction  
 Rocky Ford Springs Source Evaluation

**DRAFT**

**Legend**

 Alluvium	 Missoula Flood - snd/slt
 Loess	 Col. Rvr. Basalt
 Missoula Flood - grvls	 Water

 Approximate Groundwater Flow Direction

 Approximate Location of Groundwater Divide

1 0 1 2 Miles

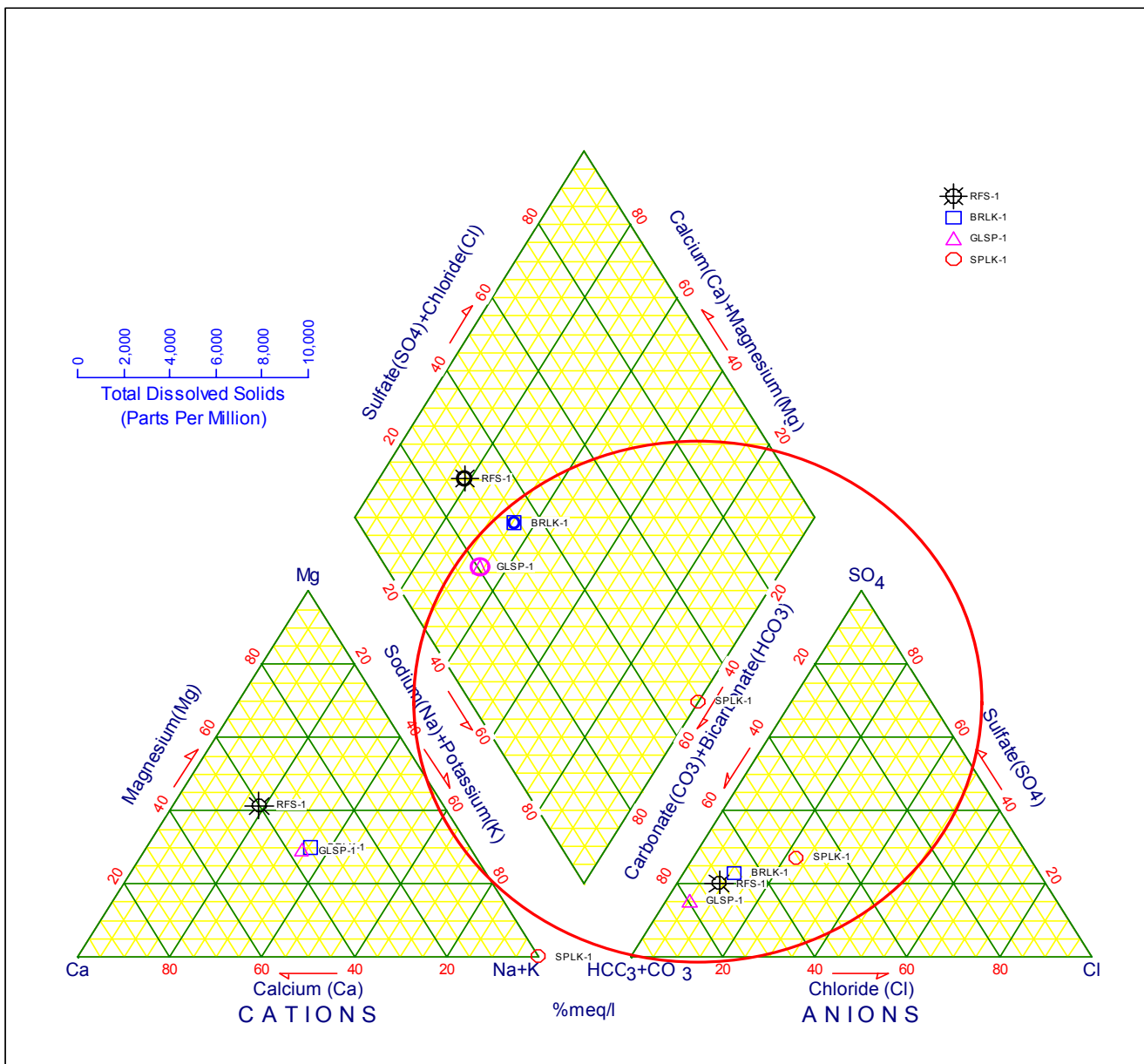
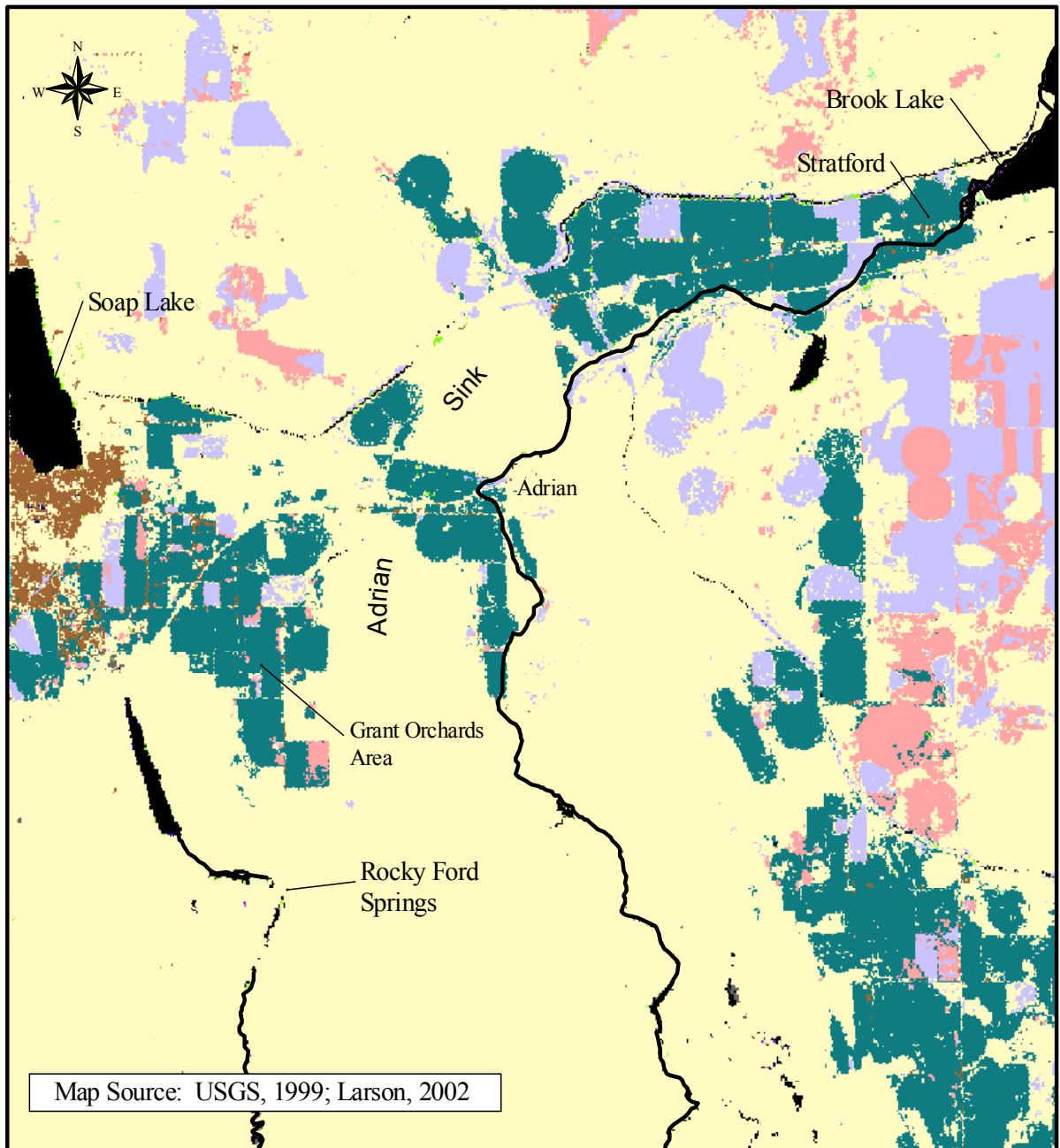


Figure A-4 – Piper Diagram Analysis  
Rocky Ford Springs Source Evaluation  
July 2001  
(with Soap Lake data)

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Note - The radius of the circles in the diamond-shaped field surrounding each station symbol represent the station concentration for total dissolved solids (TDS)



1 0 1 2 Miles

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Figure A-3  
Land Use Map  
Rocky Ford Springs Source Evaluation

#### Legend

- Water
- Small Grain Crops
- Urban Development
- Shrubland and Grassland
- Mixed Irrigated Cropland and Pasture
- Fallow Ag Land

# Findings

- Rocky Ford Springs
  - Evidence indicates Soap Lake is not in hydraulic connection with the springs
  - Spring flow hydraulically connected to shallow groundwater NE of springs
  - One possible explanation for the elevated phosphorus in the spring water — land use practices in area between spring and Brook Lake